DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, DC 20332-5000

REPLY TO
ATTN OF: LEEE

02 OCT 1988

SUBJECT: Engineering Technical Letter (ETL) 88-9:
Radon Reduction in New Facility Construction

TO: SEE DISTRIBUTION LIST

1. Purpose.

a. This letter provides guidance on radon prevention techniques that should be incorporated into new construction.

b. This ETL is authorized in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETL) dated 9 January 1986, and is to be implemented accordingly. Waivers will be processed in accordance with the procedures established by the Model Installation Program,

2. Effective Date. This ETL is effective immediately for all projects which have not reached 35 percent design.

3. Referenced Publications.

a. ASHARE 62-1981R, Ventilation for Acceptable Indoor Air Quality.

4. Description/Implementation.

a. New facilities should be designed and constructed using techniques which reduce the potential health hazard from radon exposure to occupants. Radon reduction in new facilities is based on the following principles:

(1) Minimizing pathways for radon gas to enter the structure

(2) Maintaining a positive to neutral pressure differential between the interior and exterior environments

(3) Incorporating construction features to facilitate radon removal if prevention techniques proves to be inadequate

b. The requirements for mitigation of radon in Air Force facilities are set forth in the HQ USAF/CVA letter of 23 October 1987, Implementation of the Radon Assessment and Mitigation Program (RAMP). Radon mitigation is required if a new or existing facility is assessed to have yearly average radon levels in excess of 4 pCi/l (picocuries per liter). When constructing new facilities at bases with yearly average radon levels above 4 pCi/l, radon prevention techniques should be employed.

c. The following radon prevention techniques are recommended at bases with yearly average radon levels in excess of 4 pCi/l:

(1) Place concrete slabs on grade over a 6-mil or thicker polyethylene vapor barrier and a 4 to 6 inch aggregate base material. The vapor barrier must be placed with overlapped joints between barrier sections. The integrity of the barrier must be maintained during construction. All penetrations thru the barrier must be sealed and all punctures must be repaired.

(2) Seal radon entry points in slab on grade construction with flowable polyurethane caulk placed in a prepared joint. The entry points include the perimeter floor/wall joint and the concrete slab construction joints.

(3) Seal around all plumbing, mechanical and electrical penetrations thru foundation walls/slab with polyurethane caulk/foam.

(4) Coat exterior surface of foundation walls with high quality vapor/water sealant and a 6-mil or thicker polyethelene barrier.

(5) Apply a high quality, water resistant coating to the interior surfaces of masonry foundation walls.

(6) Provide positive air ventilation in accordance with the ASHRAE ventilation standard 62-1981R.

d. The U.S. Environmental Protection Agency (EPA) has issued the attached guidance for radon reduction in new residential construction. This guidance should be used in general terms for nonresidential facilities since guidance for other building types has not been developed by EPA.

5. Point of contact for this ETL is Mr. R. J. Furlong, PE, Autovon 297-6248.

FOR THE CHIEF OF STAFF

CHARLES A. SIPPIAL, Col, USAF
Chief, Engineering Division
Directorate of Engr & Svcs

4 Atch
1. Dist List
2. Radon Reduction in New Construction, An Interim Guide, August 1987, 10 pages
3. U.S. Air Force Radon Mitigation, Student Manual, pages 175-182
4. ETL Index

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United States Environmental Protection Agency

Air and Radiation and Research and Development Washington DC 20460

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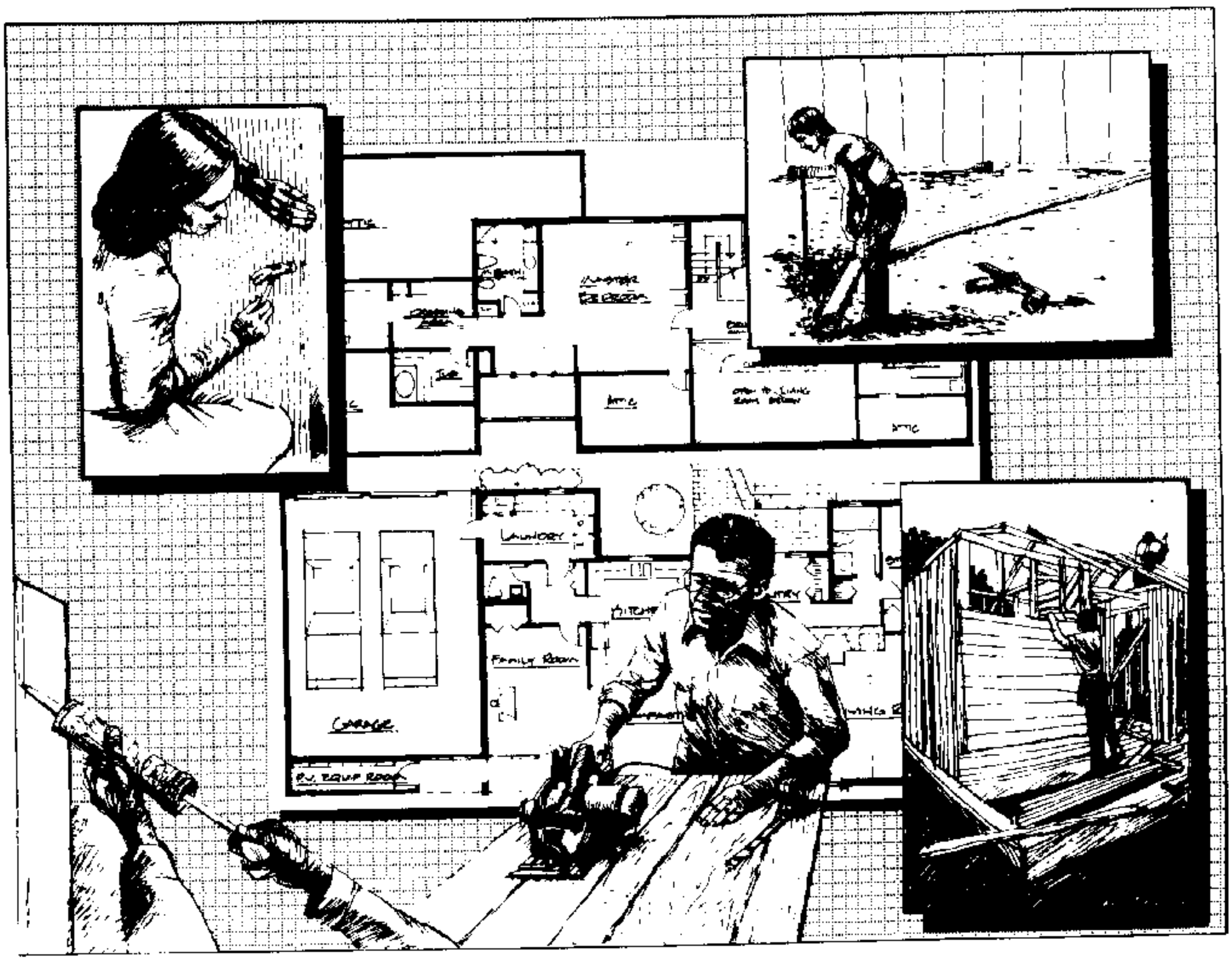
EPA

RADON REDUCTION IN NEW CONSTRUCTION

AN INTERIM GUIDE



ATCH 2

COMMENTS ON THE INFORMATION IN THIS BOOKLET SHOULD BE ADDRESSED TO:

RADON DIVISION (R-464)
OFFICE OF RADIATION PROGRAMS
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is concerned about the increas of developing lung cancer faced by persons exposed to radon in their homes. Becau families already face the problem, early emphasis was placed in identifying the da existing homes and developing cost-effective methods to make such housing safer. this early research, EPA published three documents in 1986: A Citizen's Guide to What It Is and What To Do About It, Radon Reduction Methods: A Homeowner's Guide, more detailed manual, Radon Reduction Techniques for Detached Houses: Technical G These documents were designed to help homeowners determine if they have a radon pr to present information on how to reduce elevated radon levels in their homes.

This pamphlet is the next step in attempting to reduce the radon hazard in ho is designed to provide radon information for those involved in new construction an introduce methods that can be used during construction to minimize radon entry and facilitate its removal after construction is complete. If there is concern about potential for elevated indoor radon levels, it may be prudent to use these constru techniques in new homes. The "Techniques for Site Evaluation" section of this pam outlines several methods for assessing the potential for elevated indoor radon lev decision to incorporate these construction techniques rests solely with the builde homeowner.

In addition to extensive internal EPA review, this pamphlet has been develope coordination with the National Association of Home Builders Research Foundation, I (NAHB-RF) a not or profit organization, and other federal agencies including the D of Energy (DOE), Housing and Urban Development (HUD), United States Geological Sur (USGS), and the National Bureau of Standard (NBS). It also reflects comments soli from a broad spectrum of individual experts in home construction and related indus

It is potentially more cost-effective to build a home that resists radon entr remedy a radon problem after construction. The construction methods suggested in pamphlet represent current knowledge and experience gained primarily from radon re tests and demonstrations on existing homes. Field tests are underway to develop a the most cost-effective new-home construction techniques. After completion of the tests, a more detailed "Technical Guidance" manual will be published to expand and as necessary, the interim guidance presented in this pamphlet. Accordingly, this Guide should not be referenced in codes and standards documents.

RADON FACTS

Radon is a colorless, odorless, tasteless, radioactive gas that occurs natura soil gas, underground water, and outdoor air. It exists at various levels through United States. Prolonged exposure to elevated concentrations of radon decay produ been associated with increases in the risk of lung cancer. An elevated concentrat defined as being at or above the EPA suggested guidelines of 4 pCi/l or 0.02 WL av annual exposure.* Although exposures below this level do present some risk of lun reductions to lower levels may be difficult, and sometimes impossible to achieve.

Soil gas entering homes through exposed soil and crawl spaces, through cracks openings in slab-on-grade floors, and through below-grade walls and floors is the source of elevated radon levels (Figure 1). Radon in outside air is diluted to su concentrations that it does not present a health hazard. in some small public and well-water supplies, radon is a hazard primarily to the extent that it contributes indoor radon gas concentrations. When water is heated and agitated (aerated), as or washing machine, it will give off small** quantities of radon.

Radon moves through the small spaces that exist in all soils. The speed of m depends on the permeability of the soil and the presence of a driving force caused pressure inside a home is lower than the pressure outside or in the surrounding an underlying soil. A lower pressure inside a home may result from:

- o Heated air rising, which causes a stack effect.

- o Wind blowing past a home, which causes a down-wind draft or Venturi effect.

- o Air being used by fireplaces and wood stoves, which causes a vacuum effect.

- o Air being vented to the outside by clothes dryers and exhaust fans in bathroo kitchens, or attics, which also causes a vacuum effect.

In homes, where a partial vacuum exists, outdoor air and soil gas are driven into

NEW CONSTRUCTION PRINCIPLES

The facts just discussed form the basis for the following new-construction pr

- o Homes should be designed and constructed to minimize pathways for soil gas to

- o Homes should be designed and built to maintain a neutral pressure differentia indoors and outdoors.

- o Features can also be incorporated during construction that will facilitate ra removal after completion of the home if prevention techniques prove to be inadequa

The following techniques for site evaluation and construction are based on th principles.

TECHNIQUES FOR SITE EVALUATION

The first step in building new radon-resistant homes is to determine, to the possible, the potential for radon problems at the building site. At this time, th no standard soil tests or specific

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* pCi/l, the abbreviation for pico Curies per liter, is used as a radiation unit measure for radon. The prefix "pico" means a multiplication factor of 1 trilliont Curie is a commonly used measurement of radioactivity. WL, the abbreviation for W Level, is used as a radiation unit of measure for the decay products of radon. Th relationship between the two terms is generally 200 pCi/l = 1 WL.

** The generally accepted rule of thumb for emanation of radon gas from water is: pCi/l of radon in water will normally produce a concentration of about 1 pCi/l or indoor air.

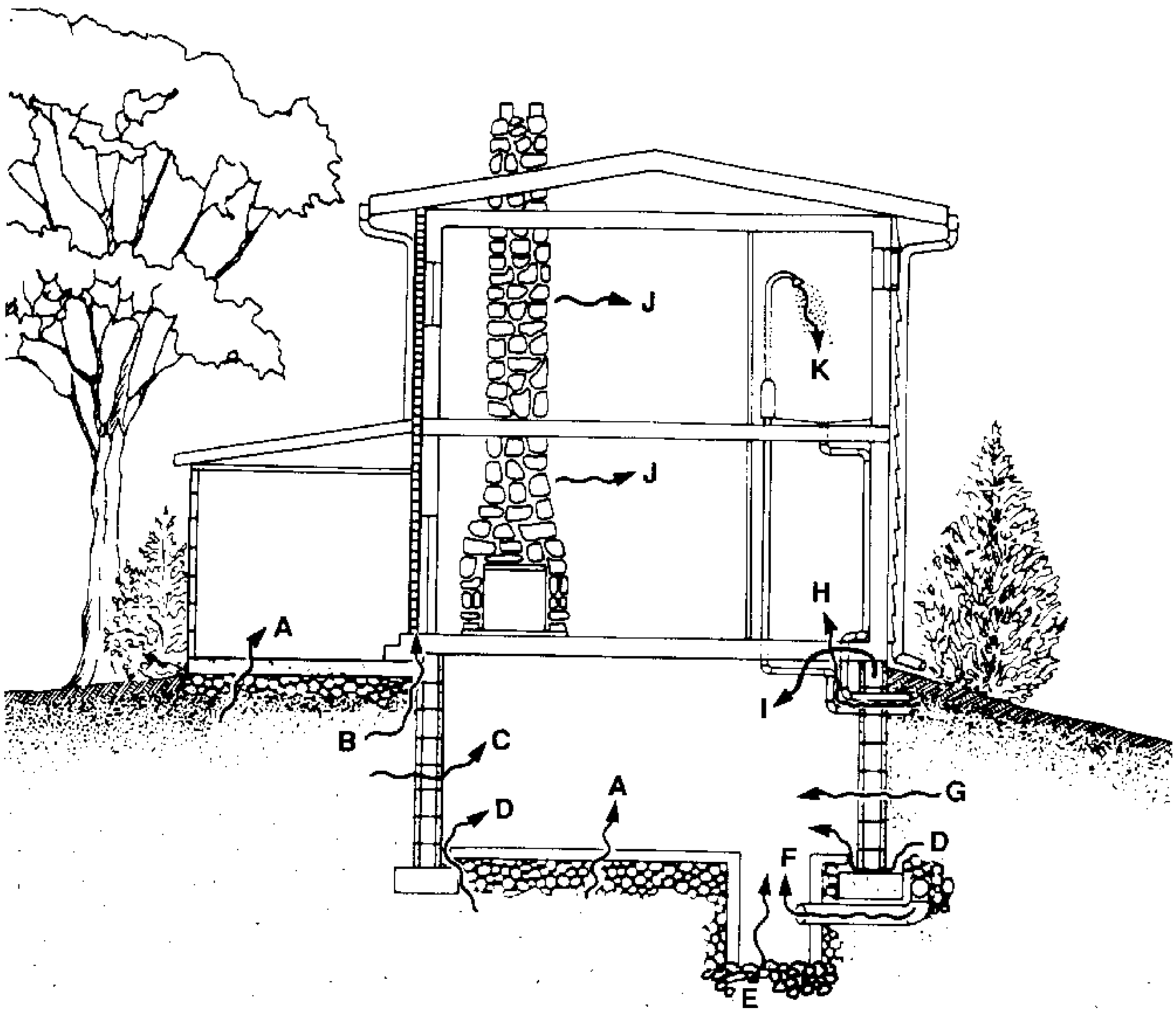


Figure 1

MAJOR RADON ENTRY ROUTES

A. Cracks in concrete slabs
B. SPACES BEHIND BRICK VENEER WALLS that rest on uncapped hollow-block foundation
C. Pores and cracks in concrete blocks
D. Floor-wall joints
E. EXPOSED SOIL, AS IN A SUMP
F. Weeping (drain) tile, if drained to open sump
G. MORTAR JOINTS
H. Loose fitting pipe penetrations
I. Open tops of block walls
J. Building materials such as some rock
K. Water (from some wells)

standards for correlating the results of soil testsat a building site with subsequ indoor radon levels. The variety of geological conditions in the United States wi probably continue to preclude establishment of any all-inclusive, nationwide stand such correlation. We can, however, estimate the radon potential at a building sit on factors other than soil tests. If the answer to any of the following questions radon problems might be anticipated and radon reduction features should be conside inclusion in construction plans.

o Have existing homes in the same geologic area experienced elevated radon leve ("Same geologic area" is defined as an area having similar rock and soil compositi characteristics.) State or regional EPA offices may be able to assist in obtainin information.

o What are the general characteristics of the soil? State and local geological agricultural offices can normally help in providing answers to the following quest soil:

--Is the soil derived from underlying rock that normally contains above-average concentrations of uranium or radium, e.g., some granites, black shales, phosphates phosphate limestones?
--Is the permeability of the soil and underlying rock conductive to the flow of ra Note that soil permeability (influenced by grain size, porosity, and moisture cont the degree to which underlying and adjacent rock structures are stable or fracture significantly affect the amount of radon that can flow toward and into a home.

o If the source of water to the site is going to be local or onsite well, have levels of radon been detected in other wells within the same geologic area? (Leve measured above 40,000 pCi/l of water could alone produce indoor radon concentratio about 4 pCi/l or above. Such levels are considered excessive.) State or local he agencies, departments of natural resources, or environmental protection offices ma to assist in providing this information. Testing well water for radon before the built could provide an additional indication of a potential radon problem. If exc radon levels are confirmed, a granular activated-carbon filtration system or an ae system might be designed into the plumbing plan.

CONSTRUCTION TECHNIQUES

Some of the radon prevention techniques discussed below are common building p in many areas and, in any case, are less costly if accomplished during constructio to retrofit existing homes with the same features would be significantly higher. these construction techniques do not require any fundamental changes in building d there is a continuing need for quality control, supervision, and more careful atte certain construction details. Construction techniques for minimizing radon entry grouped into two basic categories:

o Methods to reduce pathways for radon entry.

o Methods to reduce the vacuum effect of a home on surrounding and underlying s Typically, the techniques in both categories are used in conjunction with each oth

METHODS TO REDUCE PATHWAYS FOR RADON ENTRY (FIGURE 2)

IN BASEMENT AND SLAB-ON-GRADE CONSTRUCTION:

o Place a 6-mil polyethylene vapor barrier under the slap. Overlap joints in t barrier 12 inches. Penetrations of the barrier by plumbing should be sealed or ta care should be taken to avoid puncturing the barrier when pouring the slab.

o To minimize shrinkage and cracks in slabs, use recommended water content in c mix and keep the slap covered and damp for several days after the pour.

o To help reduce major floor cracks, ensure that steel reinforcing mesh, if use imbedded in (and not under) the slab. Reducing major cracks in footings, block fo and poured-concrete walls will reduce the rate of radon entry. Radon can, however homes through even the smallest cracks in concrete slabs and walls if driving pres applied to those surfaces.

o The most common radon-entry pathways are inside perimeter floor/wall joints a control joints between separately poured slab sections. To reduce radon entry thr these joints, install a common flexible expansion joint material around the perime the slab and between any slab sections. After the slab has cured for several days or depress the top 1/2 inch or so of this material and fill the gap with a good qu non-cracking polyurethane or similar caulk. Similar techniques for sealing these may also be used.

o In some areas, basement slabs are poured with a French Drain channel around t perimeter. To be effective, this moisture control technique requires that the flo joint be open to permit water to seep out into the sub-slab area. To reduce radon through such open joints, it may be necessary to install a perforated drain pipe I the slab, adjacent to the footing and imbedded in aggregate, and to tie this pipe sub-slab ventilation system to draw radon gas away from the French Drain joint (Fi For additional information on water control techniques, refer to National Associat Home Builders (NB) publication BASEMENT WATER LEAKAGE: CAUSES, PREVENTION, AND CO

o When building slap-on-grade homes in warm climates, pour the foundation and s single (monolithic) unit. If properly insulated below grade-level, shallow founda slabs can also be poured as a single unit in cold climates.

o Remove all grade stakes and screed boards and fill the holes as the slap is b finished. This will prevent future radon pathways through the slab, which might o be created as imbedded wood eventually deteriorates.

o Carefully seal around all pipes and wires penetrating the slap paying particu attention to bathtub, shower, and toilet openings around traps.

o Floor drains, if installed, should drain to daylight, a sewer, or to a sump w discharge. Floor drains should not be drained into a sump if such a pit will be u part of a sub-slab ventilation system. Suction on the sump could be defeated by a line to the floor drain.

o Sumps should be sealed at the top. In closed sumps used for sub-slab ventilation systems, the continuous flow of moist air through the sump can cause r corrosion of exposed sump pump motors. For this reason, submersible-type sump pum recommended for closed-sump applications.

IN BASEMENT AND CRAWL SPACE CONSTRUCTION:

o Seal or cap the tops of hollow-block foundation walls using one of the techni shown in Figure 2.

o Carefully seal around any pipe or wire penetration of below-grade walls.

o Exterior block walls should be parged and coated with high-quality vapor/wate sealants or polyethelene films. For additional information on wall sealing, refer publication BASEMENT WATER LEAKAGE: CAUSES, PREVENTION, AND CORRECTION. Several products for use on exterior walls are designed to provide an airway for soil gas the surface outside the wall rather than being drawn through the wall. Similar ma may also be used in sub-slab ventilation applications.

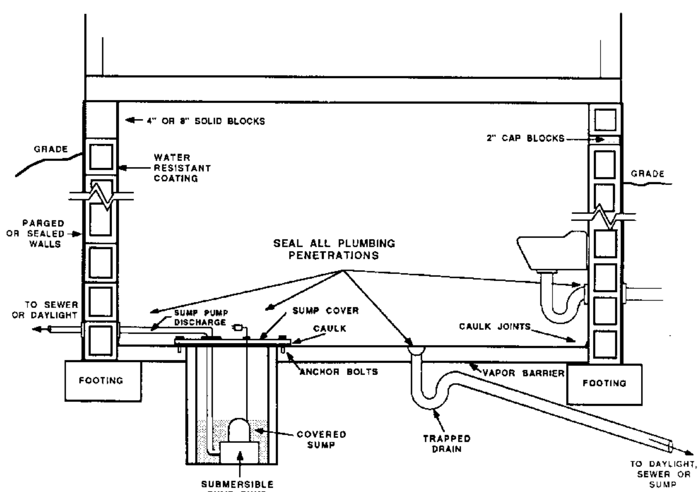
o Interior surfaces of masonry foundations may be covered with a high-quality, resistant coating.

o Heating or air-conditioning ductwork that must be routed through a crawl spac beneath a slab should be properly taped or sealed. This is particularly important return air ducting,which is under negative pressure. Due to difficulty in achievi permanent sealing of such ductwork, it may be advisable to redesign heating and ve systems to avoid ducting through sub-slab or crawl space areas, particularly in ar elevated soil radon levels have been confirmed.

o Install air-tight seals on any doors or other openings between basements and crawl spaces.

o Seal around any ducting, pipe, or wire penetrations of walls between basement adjoining crawl spaces, and close any openings between floor joists over the divid

o Place a 6-mil polyethelene vapor barrier on the soil in the crawl space. Use inch overlap and seal the seams between barrier sections. Seal edges to foundatio



METHODS TO REDUCE PATHWAYS FOR RADON ENTRY

Figure 2

METHODS TO REDUCE THE VACUUM EFFECT (FIGURE 3)

o Ensure that vents are installed in crawl space walls and are sized and locate accordance with local building practices. Adequate ventilation of crawl spaces is defense against radon entry in crawl space-type homes.

o Reduce air flow from the crawl space into living areas by closing and sealing openings and penetrations of the floor over the crawlspace.

o To reduce the stack effect, close thermal bypasses such as spaces around chim and plumbing chases. Attic access stairs should also be closed and sealed. (Note Because of potential heat buildup, most codes prohibit insulating around recessed lights. Such lights should therefore be avoided in top-floor ceilings. As an alt use recessed ceiling lights designed to permit insulation or "hi-hat" covers and s minimize air leakage.)

o Install ducting to provide an external air supply for fireplace combustion.

o In areas frequently exposed to above-average winds, install extra weather sea above the soil line to reduce depressurization caused by the Venturi effect. Such will also save energy and reduce the stack effect.

o Air-to air heat exchange systems are designed to increase ventilation and imp indoor air quality. They may also be adjusted to help neutralize any imbalance be indoor and outdoor air pressure and thus reduce the stack effect of the home. The not, however, be relied upon as a stand-along solution to radon reduction in new construction. (A slightly positive pressure, in the basement, may contribute to r radon flow into a home.)

CONSTRUCTION METHODS THAT WILL FACILITATE POST-CONSTRUCTION RADON REMOVAL (FIGURE

Recognizing that radon prevention techniques may not always result in radon l below the suggested guidelines of 4 pCi/l average annual exposure, there are sever additional construction techniques that can be used to facilitate any post-constru radon removal that may be required.

o Before pouring a slab, fill the entire sub-floor area with a layer (4 inches pea gravel or larger, clean aggregate to facilitate installation of a sub-slab ven system.

o Lay a continuous loop of perforated 4-inch diameter drain pipe around the ins perimeter of the foundation footing. Run the vent from this loop into the side of sump that can, if necessary, be equipped with a fan-driven vent to the outside. I configuration, the drain pipe loop can aid in water seepage control as well as rad reduction.

o As an alternative to the vented interior drain pipe loop, a similarly vented loop can be laid outside the foundation footing.

o In areas where water seepage into below-grade spaces is not a problem and sum are not installed, exterior or interior drain pipe loops can be stubbed-up outside or through the slab and can be available for use as sub-slab ventilation points if

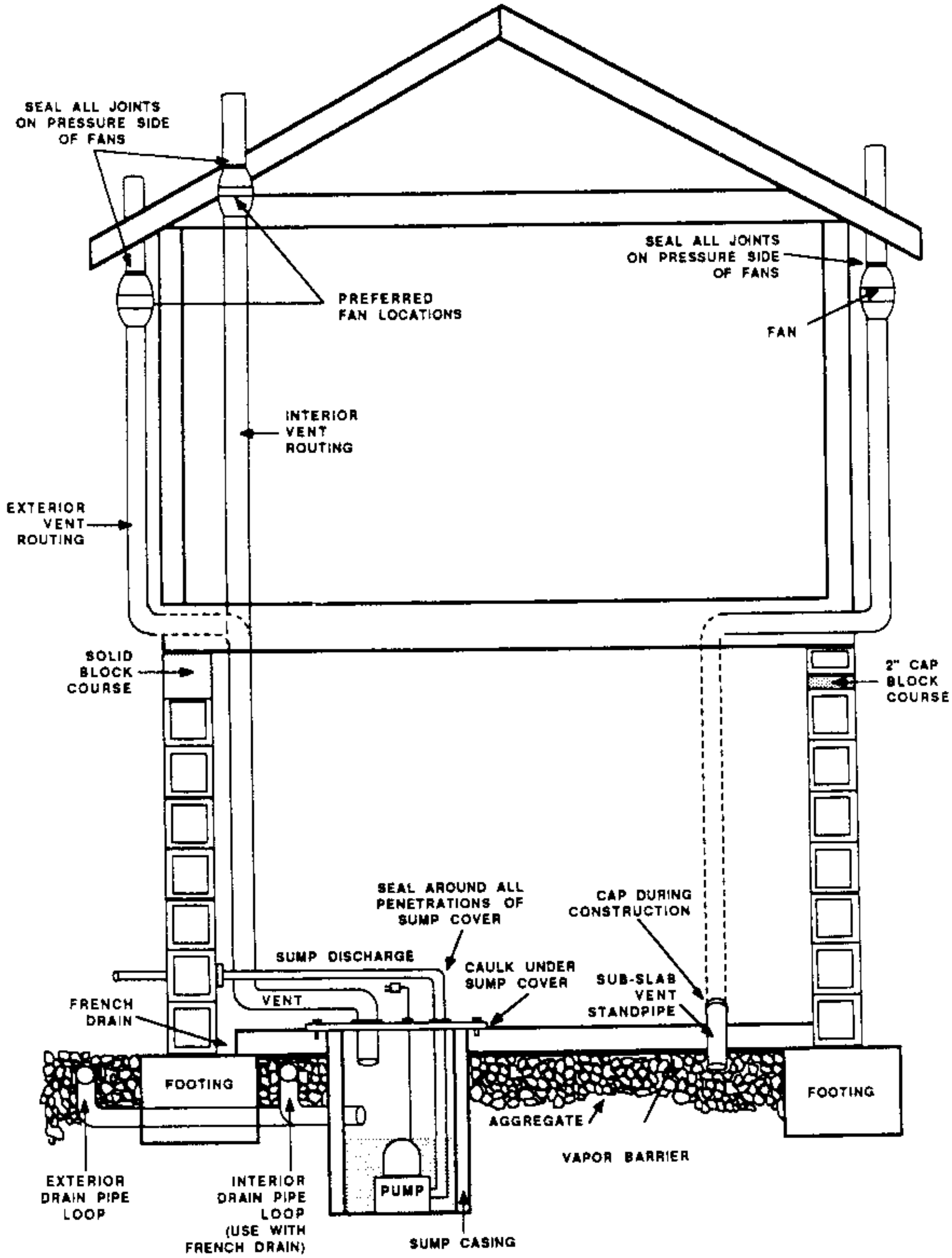
o The soil beneath a slab can also be ventilated using the following technique: to pouring the slab, insert (in a vertical position) one or more short (12-inch) l 4-inch minimum diameter PVC pipe into the sub-slab aggregate and cap the top end.

construction is complete, these standpipes can, if necessary be uncapped and conne one or more convection stacks or fan-driven vent pipes. When positioning these st choose locations permitting venting to the roof through already planned flue or pl chases, interior walls, or closets. In homes where flue or other chases are restr size or not easily accessible, it may be less expensive to go ahead--during the fr rough-in plumbing/electric phase of construction--and complete the vent pipe hooku temporarily terminating the vent in the attic along with an electric outlet for fu installation. Experience has shown that in homes with higher radon levels--above -convection (passive) venting may not produce acceptable radon reductions. If low levels are expected and passive venting is attempted, performance is improved by u inch diameter vent routed straight from the floor through the roof, with minimum b

Drilling 4-inch holes through finished slabs for insertion of vent pipes is a alternative to this technique.

o To create the necessary convection flow, radon prevention techniques that inv passive venting normally require stacks that pass through the floors and roof. Wh (fan-driven) systems are installed, venting through to the roof is still preferred Recognizing, however, that active systems can be vented through the band joist or grade walls to the outside, it is considered advisable in such active systems to p the exit point of the vent pipe at or above the eave line of the roof and away fro doors or windows. This will preclude any possible recirculation of air containing concentrated radon gas back into the house.

o In homes where an active (fan-driven) sub-slab ventilation system has been in it may be necessary to provide make-up air to avoid back drafting.



METHODS TO FACILITATE POST-CONSTRUCTION RADON REMOVAL

Figure 4

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SOURCE OF INFORMATION

If you would like further information or explanation on any of the points mentione booklet, you should contact your State radiation protection office or home builder association.

If you have difficulty locating these offices, you may call your EPA regional listed below. They will be happy to provide you with the name, address, and telep number of these contacts.

STATE-EPA REGION

ALABAMA-4
ALASKA-10
ARIZONA-9
ARKANSAS-6
CALIFORNIA-9
COLORADO-8
CONNECTICUT-1
DELAWARE-3
DISTRICT OF COLUMBIA-3
FLORIDA-4
GEORGIA-4
HAWAII-9

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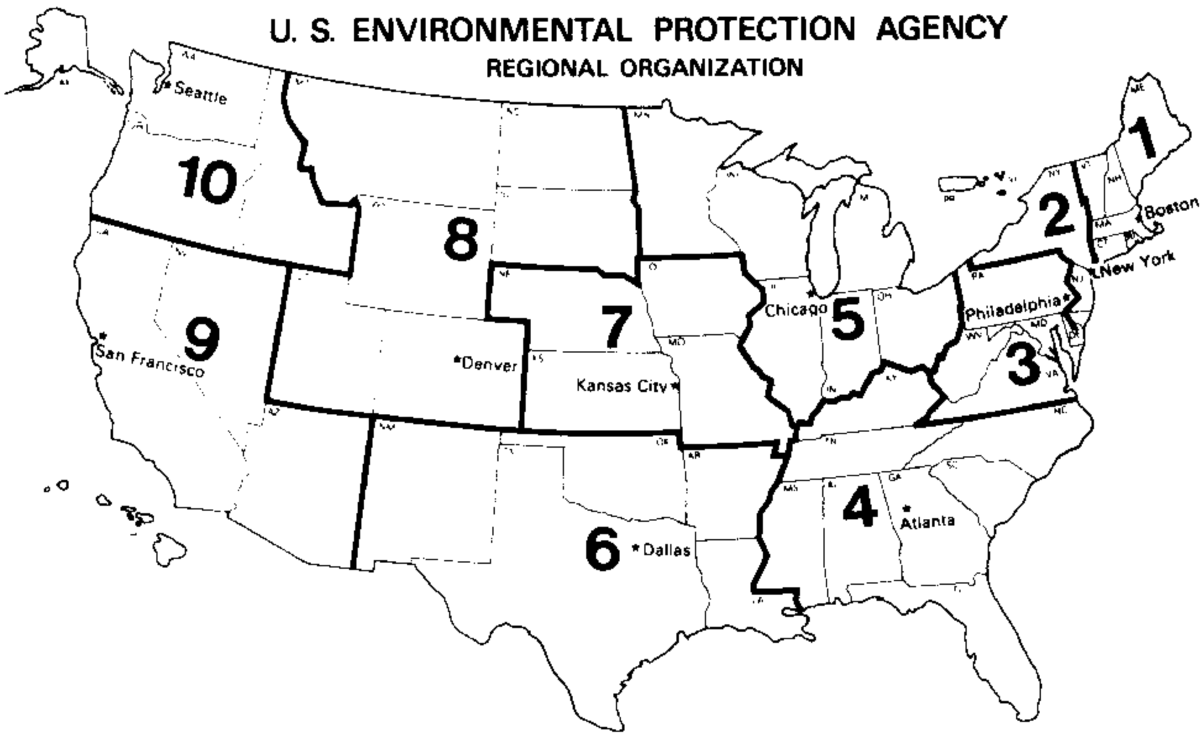

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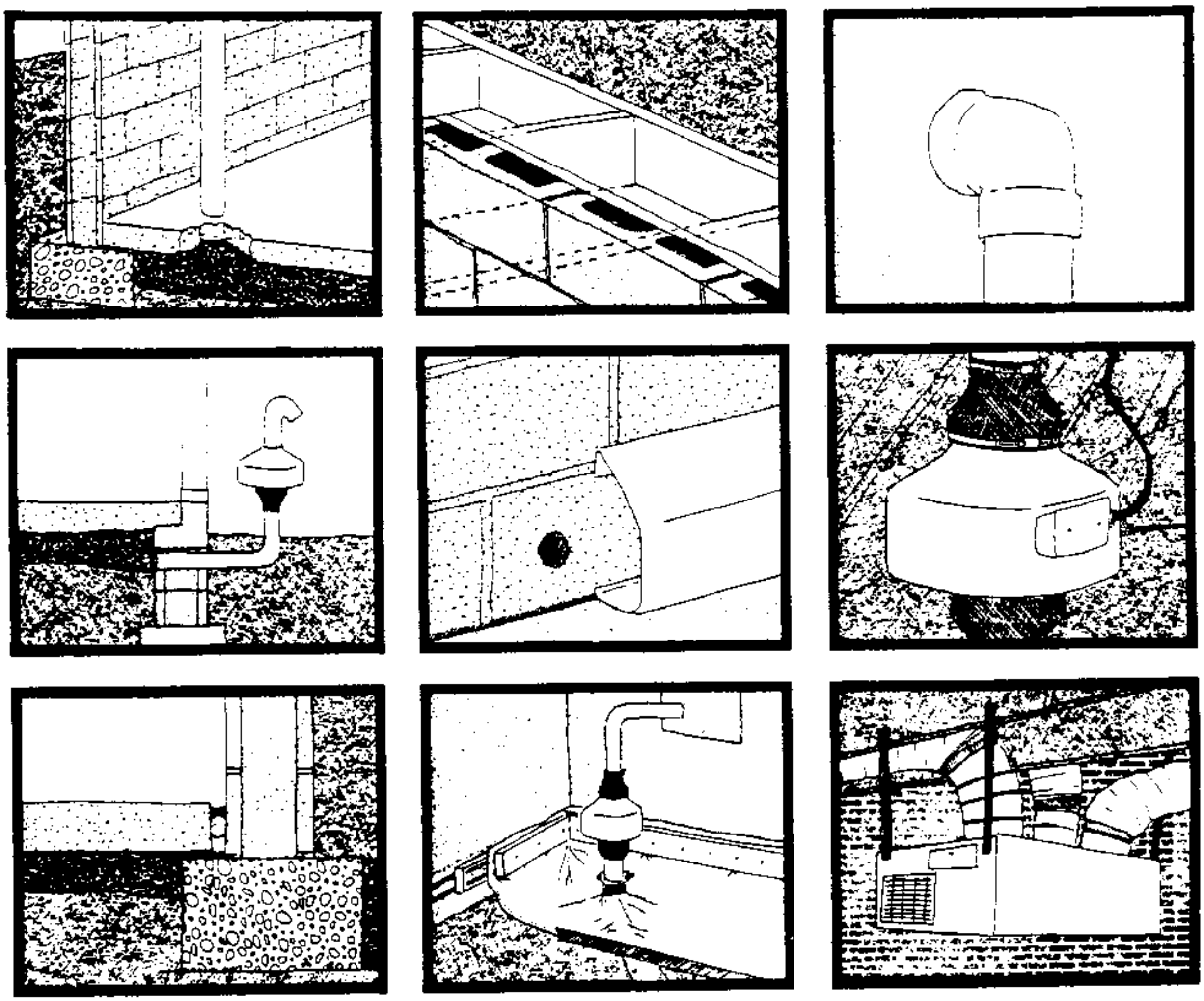
RADON MITIGATION



United States Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

ATCH 3

REDUCING INDOOR RADON

UNIT VII

NEW CONSTRUCTION

INTRODUCTION

The best way to avoid a potential radon problem is by taking steps during the struction of a new house. Remediation techniques which may cost several thousand to retrofit in an existing building can sometimes be installed at the time of cons for a few hundred dollars. The situation is very similar to controlling water and vapor. Excavating soil around an existing house and installing footing drains and proofing can be costly, but the drainage system can be installed quite easily when house is under construction. Many builders feel thiS is cheap insurance and routi install drainage and damp proofing on new house foundations. This may well become attitude towards radon in new construction, particularly in areas where many exist houses have had high concentrations.

Very little research has been done to date that demonstrates radon resistant struction. The problem is that it is difficult to tell whether the treatment to k out has worked, or if the house would not have had a problem anyway.

SITE TESTS

It would be very beneficial if there were a simple test to determine whether cular housing site had a problem or not. Enough testing can characterize a buildi however, the problem is that when the excavation and site work is done the site is tially modified. Several tests done at depths of 12" to 30" might completely miss permeable layer of soil with high radon concentrations that starts four feet down.

Comparing radon measurements taken from the soil to those taken inside nearby ings does not show a good correlation. Rather than attempting to characterize a s through extensive testing, it may be cheaper to build a radon-resistant house. So testing may be more appropriate for large scale development than for individual si Although there is usually a large scatter in the data it may be possible to find a limit of soil gas concentrations. Very few problem houses have been found on Soil radon concentrations less than 400 to 600 pCi/L (Ref. 3).

APPROACHES TO RADON-RESISTANT NEW CONSTRUCTION

Radon control techniques for existing houses fall into one of two categories (Ref.

- o preventing the entry of radon into the living area
- o reducing radon concemtration after the gas has entered the house

Most of the ideas for constructing a radon-resistant building fall into the catego

- o preventing entry
- o providing for future installation of a mitigation system

PREVENTING ENTRY

For new construction, two methods can be used to prevent radon entry. One me involves making physical barriers that seal all the openings in the foundation. T is building the house in such a way that it does not bring soil air into the basem

PHYSICAL BARRIERS

Coatings, films, caulks, and the foundation materials themselves all can be u make a physical wall between radon in the soil and house air.

WALLS

Foundation walls constructed with poured concrete are more resistant to radon than hollow block walls. When using block, the inside and outside of the wall sho parged. A high quality damp proofing on the outside of the wall should be applied Pressing 6 mil poly into the coating before it cures will create a membrane that c future cracks. Reinforcing the wall with plasters, and vertical and horizontal re rod will help to prevent cracking.

Use a solid block to cap the block wall. The grouting should be completed ev ends of the block. The idea is to seal the top of the wall. If it is done as the course from the top there are sill open cores at the top for setting the sill bolt

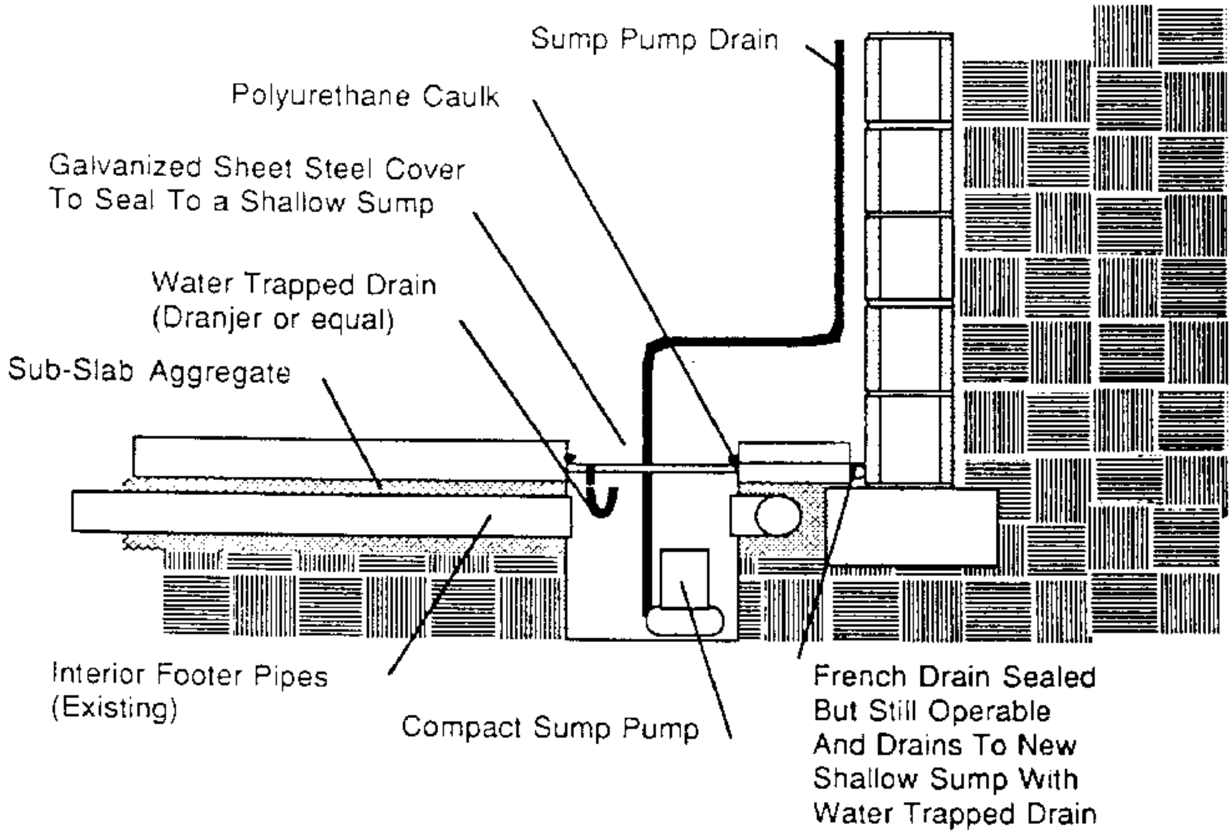
FLOORS

Poly vapor barriers under the slabs are important for moisture but their effe at keeping out radon is uncertain. The problem is in getting air-tight seams, edg seals at penetrations. Poly vapor barriers should help to span any cracks that de the concrete.

Because the concrete slab is the best floor defense, a good deal of attention be paid to sealing joints and penetrations and preventing cracks. The use of stee mesh to help prevent cracks from opening is common. Plastic additives are availab make concrete less likely to crack to begin with, and make it easier to handle wit mix. Because shrinkage is due to water evaporating, there is less shrinkage if plasticizers are added. Slowing the cutting process by coating the green (un-cure concrete with a plastic sealer also helps prevent shrinkage cracks. No stakes or framing should be cast into the concrete which may form a radon entry route later.

It is a good idea to set up control joints in the concrete so that any cracks form will be in a controlled location. This way, it will be easy to seal later wi polyurethane caulks. Several companies make expansion joint materials that allow half inch to be easily torn out after the concrete has set. This leaves a 1/2" x channel in which to pour urethane caulk. They can be used in control joints and a breaker at the edge of the slab. Because it is important to seal the slab/wall jo french drains or perimeter canals should not be used for water control. Alternate systems such as interior and exterior footing drains should be employed.

Sump holes must also be sealed. Ideally they should be eliminated, and water be drained to daylight if possible. In the many cases where this can't be done an cover should be fitted to the sump hole. Figure VII-1 shows this detail.



Converting Sump Hole into a Shallow Sump

Note: This is a standard detail. Ignore any construction features shown here whi appear in your house.

SOURCE: BRE

FIGURE

The cover should be made of a material that can withstand damp conditions. G sheet metal or treated plywood have been used. A compact submersible sump pump al enough room to install a recessed cover a few inches below the floor level. This shallow sump which can be drained through a water trap to the sump below. There a manufacturers who sell sumps with gasketed covers. Some of them are set up with a fitting or even the fan itself to make sub-slab ventilation very simple. Another manufacturer produces a water trapped drain that installs in the cover.

Plumbing and utility holes through the walls or floors need to be sealed. Th especially true of showers and tubs. Underneath these is often a large opening fo water trap and for some flexibility in installation. To prevent radon entry, firs the framing that was used to bulkhead off the opening. After the tub or shower ha installed, seal the earth with pourable roofing cement on poly, or with a two part polyurethane foam.

Water pipes are often wrapped in pipe insulation as they pass through the sla should be removed before the slap is pored, and pitch should be applied to the pip prevent corrosion. Pipe penetrations can be sealed with polyurethane caulk.

A condensation line should be run from the air conditioner to a water trapped or a condensate pump can be installed to pump water to a water trapped drain or ou joist. No pipe should run directly through the slap. Even a trap installed in th condensate line may dry up in the winter time, allowing soil gas to enter.

Crawlspaces are a special floor situation. They can be dealt with in two way is by treating them as a small basement and doing all the things recommended here basements. Include them as part of the conditioned space. Put down a concrete fl the joints, make it easy to do sub-slab ventilation and use them to store the holi ornaments.

The other approach is to make barriers and ventilate. This involves putting inches of stone pebbles (#1,#2, or #57) on the earth floor and covering it with a film or 2" to 3" of concrete. As many cracks nd holes as possible should be seale the living space and the crawlspace, and the floor should be insulated. Passive v should be added to at least two walls in accordance with local, state or model cod BOCA).

BARRIERS THAT INTERFERE WITH PRESSURE DIFFERENTIALS

Another approach involves planning the house so that either very little sucti on the basement, or so that soil air has easier pathways to follow than those goin the building.

REDUCING NEGATIVE PRESSURES

This can be accomplished by supplying outside air to the ares of the house wh being exhausted. This includes kitchen exhausts, bath fans, furnaces and boilers, fireplaces (which must have make up air by code in many places). The thermal stac is a little more difficult to supply air for because it is not a point exhaust. H the large openings in attics may be sealed to make the house a little less like a Many manufacturers are producing air intake fittings and systems to supply make up houses. Some manufacturers have designed whole ventilation systems that allow air (REP PB column) At least one manufacturer of downdraft kitchen ranges recommends up air be supplied to their units. Manufacturers to heating equipment offer a lar variety of units with dedicated combustion air. Heat recovery ventilators can hel negative pressure and preheat the incoming fresh air.

DRAINAGE BOARDS

I may be possible to use drainage boards on the outside of a foundation to gi soil air a route to the outside air which offers less resistance than going throug house. These materials essentially make an air space around a foundation which al water to run down to the footing drains more readily than through the walls. If t passively vented to the outside air, then it could lower the driving pressure diff between the outside air and the basement air. It also could reduce the soil conce immediately around the house by dilution.

PROVIDING FOR FUTURE INSTALLATION OF A MITIGATION SYSTEM

If a house ends up with a radon problem in spite of the best efforts to keep steps taken during construction designed to facilitate later mitigation measures w time and money.

At least 4" of stone pebbles that are clean and relatively uniform size (e.g. #1,#2,#57) should be placed under the slab. This not only will make it possible t radon problem with a single suction point later on, it will keep water from coming through the floor if the layer is drained away to daylight or to a sump hole.

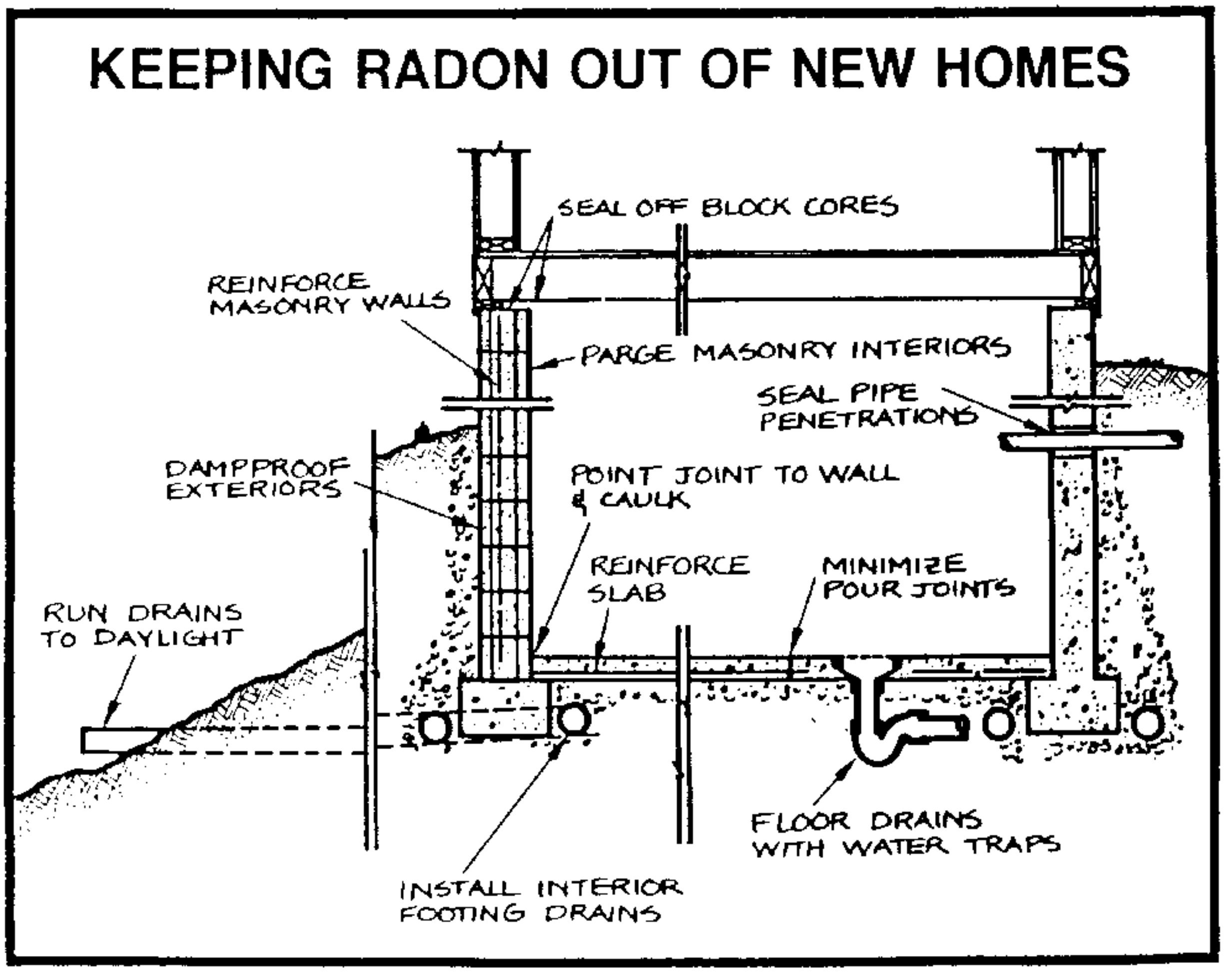
Perforated interior and exterior footing drains should be used. On the exter should be surrounded by clean stone pebbles. on top of the pebbles should be filt to keep soil from clogging the stone or pipe. This pipe should drain to daylight possible. Any drains to daylight should have a reverse flow valve installed at th so that if a fan becomes needed to power a soil ventilation technique, air will no drawn in through the drain. If it is not possible to drain to daylight, the pipes be drained to a sealed interior sump pump.

Anticipate setting up a soil de-pressurization fan in the house. It may be a idea in risky areas to run a vent pipe from under the slab out the roof like a plu vent stack. This can easily be powered by a fan later if needed and can eliminate deal of work in installing a soil depressurization system.

CONCLUSION

There are a reasonable number of things that can be done to make new houses m resistant. Figure VII-2 shows a schematic house containing the features discussed

They all fall into the categories of preventing radon entry and/or providing alternate mitigation techniques if needed. Many of the things already done to pre water entry will help in the battle against radon entry. Manufacturers are alread producing hardware to help in this process, but most ideas can be implemented with currently existing products. There are several research projects being conducted the USEP, NYSERDA and Homebuilders Associations to evaluate the effectiveness of t approaches.



SOURCE: BRENNAN / SOLAR AGE M

FIGU